

# PSO-TUNED PID CONTROLLER OF A GANTRY CRANE SYSTEM

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# PSO-TUNED PID CONTROLLER OF A GANTRY CRANE SYSTEM

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Specially dedicated to my beloved mother, father, wife, son and friends who have encouraged, guided and inspired me throughout my journey of education.

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## **ABSTRACT**

This project presents development of an optimal PID controller for controlling the nonlinear gantry crane system. The tuning method of Particle Swarm Optimization (PSO) with priority based fitness and linear weight summation approaches are implemented for finding optimal PID parameters. The effectiveness of both method are observed in order to find the optimal performances of system. The system dynamic model is derived using Lagrange equation. A combination of PID and PD controllers is utilized for positioning and oscillation control of the system. System responses including trolley displacement and payload oscillation are observed and analyzed. Simulation is conducted within Matlab environment to verify the performance of the controller. It is demonstrated that implementation of PSO is effective to move the trolley as fast as possible to the desired position with low payload oscillation.

## **ABSTRAK**

Projek ini membentangkan pembangunan pengawal PID yang optimum untuk mengawal sistem kren gantri tidak linear. Kaedah penalaan bagi Particle Swarm Optimization (PSO) dengan menggunakan pendekatan keutamaan kecergasan dan penjumlahan pemberat secara linear dilaksanakan untuk mencari parameter PID yang optimum. Keberkesanan kedua-dua kaedah dipatuhi bagi mencari prestasi sistem yang optimum. Model sistem dinamik diperolehi menggunakan persamaan Lagrange. Gabungan pengawal PID dan PD digunakan untuk mengawal kedudukan dan ayunan sistem. Tindak balas sistem termasuk anjakan troli dan ayunan beban diperhatikan dan dianalisis. Simulasi yang dijalankan adalah dalam persekitaran Matlab untuk mengesahkan prestasi pengawal. Ia menunjukkan bahawa pelaksanaan PSO adalah berkesan untuk menggerakkan troli secepat mungkin ke kedudukan yang dikehendaki bersama ayunan beban yang rendah.

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## LIST OF ABBREVIATIONS

PID	-	Proportional Integral Derivative
PD	-	Proportional Derivative
PSO	-	Particle Swarm Optimization
MOPSO	-	Multi Objective Particle Swarm Optimization

## LIST OF SYMBOLS

$SSE$	-	Steady State Error
$OS$	-	Overshoot
$T_s$	-	Settling Time
$\theta_{max}$	-	Maximum Angle of Payload Oscillation
$T$	-	Period of 1 Cycle Oscillation
$P$	-	Proportional
$I$	-	Integral
$D$	-	Derivative
$K_P$	-	Parameter of Proportional
$K_I$	-	Parameter of Integral
$K_D$	-	Parameter of Derivative
$v^i$	-	Velocity of Particles
$x^i$	-	Position of Particle
$P_{BEST}$	-	Personal Best
$G_{BEST}$	-	Global Best
$c_1$	-	Coefficient Value for Cognitive Behavior
$c_2$	-	Coefficient Value for Social Behavior
$r_1$ and $r_2$	-	Random Function Values Between 0 to 1
$\omega$	-	Initial Weight
$w_{SSE}$	-	Weight for Steady State Error
$w_{OS}$	-	Weight for Overshoot
$w_{T_s}$	-	Weight for Settling Time

$V$	-	Input Voltage
$m_1$	-	Payload Mass
$m_2$	-	Trolley Mass
$l$	-	Cable Length
$x$	-	Horizontal Position of Trolley
$\theta$	-	Payload Oscillation
$T$	-	Torque
$F$	-	Force
$g$	-	Gravitational
$B$	-	Damping Coefficient
$R$	-	Resistance
$K_T$	-	Torque Constant
$K_E$	-	Electric Constant
$r_P$	-	Radius of Pulley
$z$	-	Gear Ratio



## **CHAPTER 1**

### **INTRODUCTION**

#### **1.1 Gantry Crane System**

In our daily life, the strength of human is very limited and causes the use of boundless manpower in the industry to handle heavy materials. In order to utilize of manpower, heavy machinery is needed to make the work become easier and less time to complete the task. The improvement of technology made gantry crane system is one of the suitable as a heavy machinery to be used and frequently employed in the transport industry for the loading and unloading of huge materials. It supported by two or more legs and the trolley has been designed on the top of it as shown in Figure 1.1. Crane operator will seat inside the trolley and responsibility to control and move the trolley with the payload hanged via cable hook which is directly connected to the trolley. The trolley will move along the horizontal rail until reach to the desired location. Based on a real crane system, it may allow a trolley movement until 80 to 90 meters (Butler *et al.* 1991).



Figure 1.1: Gantry Crane

Gantry cranes are commonly used in material handling system in factories, warehouse, shipping yards and nuclear facilities where heavy loads must be moved with extraordinary precision. It is desirable to move the trolley to a required position as fast as possible with low payload oscillation. However, the crane acceleration required for motion, always induces undesirable load swing (Butler *et al.* 1991). At higher speed, these sway angles become larger and significant, and cause the payload hard to settle down when unloading. This unavoidable frequently load swing causes efficiency drop, load damages and even accidents.

Safety issues must be prioritized and emphasized because it involves the transfer of heavy loads. This work should be done with full concentration and carefully. Consciously or not, there were many cases and accidents in handling the crane. For instance, the latest incident was happened on February 2, 2012 at Port Mann Bridge, Canada where 700 tones of gantry crane collapsed. At the time of the accident, the distinctive yellow gantry crane was holding the 90 tones section of the

bridge deck. However, one of the crane support legs gave way and buckled, causing the crane to slip off its tracks in handling the heavy load as shown in Figure 1.2. Based on this situation, it is not only harmful to employees but also a danger to other people nearby. With the limitations of human ability, many factors need to be considered to ensure that such an accident can be reduced and prevented in future. Due to this problem, control engineering is seen to be able to reduce the number of accidents.

This project is focuses on a gantry crane system. There are two important roles to be considered which are position of trolley and payload oscillation. Trolley should move as fast as possible while payload should not give huge impact on the swing angle that can cause accident and harm people surroundings. These two factors will be decisive to the stability of gantry crane performances. In order to control both of it, controller in needed.

## **1.2 Problem Statement**

- i. Trolley acceleration always induces undesirable load swing. By increasing speed of the trolley, swing angle becomes larger. Due to this swing angles, a lot of time is needed to unload until the payload stop from swaying.
- ii. Most of the gantry crane is controlled by experts and experience operators manually in order to stop the swing and trolley at an accurate position. Manual control is one of the factors of accident due to the negligence and carelessness of human. It becomes more dangerous if load is become larger.



Figure 1.2: Overview of the Accident

### 1.3 Significant of Project

- i. According to previous work that has been conducted by researchers, a lot of controllers has been designed in order to find the best performance of gantry crane systems. Most of the controllers are designed to control the trolley position and payload oscillation. However, it has not been solved as expected results.
- ii. Since most of industries are used PID controller widely, this project is proposed on using a simple but effective PID controller for gantry crane system. This is due to simple structure and robust performances in a wide range of operating conditions.
- iii. However, there are some difficulties in finding the optimal value of PID parameters. Thus, many researchers have begun to use optimization methods in finding the most appropriate values. Therefore, Particle Swarm Optimization (PSO) is chosen and implemented due to simple optimization compared to the other optimization methods. Developing a simple and effective tuning method for PID controller can significantly contribute to the advancement of control system knowledge and catering the industrial needs.

## **1.4 Objectives of Project**

There are two objectives need to be achieved for this project.

- To obtain optimal PID controller gains for a gantry crane system using PSO.
- To verify the performance of the gantry crane in terms of position and payload swing.

## **1.5 Scopes of Project**

In order to ensure this project is conducted within the boundary, three scopes are listed.

- Implement PID controller in order to control the performance of gantry crane system.
- Apply PSO method in finding the optimal PID gains of gantry crane system.
- Use MATLAB and Simulink in writing PSO code and the simulation.

## **1.6 Project Report Outline**

This section presents the outlines of the project report. This report is organized into five chapters and each of these chapter is generally explained.

**Chapter 1** gives a brief introduction regarding on actual implementation of gantry crane in real life situation. Problem statement, objectives, and significant of the project work will be stated and listed clearly.

**Chapter 2** discusses literature review on gantry crane systems and some related works. The development of controller and optimization approach for the system is reviewed based on previous researchers findings.

**Chapter 3** discusses characteristic of PID controller and PSO development. Two techniques of PSO methods will be introduced in order to tune five PID parameters. At the end of the chapter, controller and optimization method are chosen in order to implement in this work.

**Chapter 4** discusses the gantry crane model and mathematical expression used in this project. The derivation will lead to a state space equation. Several published papers are used for validation of the derived model.

**Chapter 5** consists of two phases of work. The first phase involves analysis of gantry crane model without PID controller. The behavior of gantry crane will be analyzed based on four different setting parameters. The second phases involves analysis with PID controller and it will be tuned by using two techniques of PSO methods. At the end of this chapter, both results will be compared in order to identify the best technique tuning method.

**Chapter 6** contains conclusion regarding on the whole work and recommendation for the future works.

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